The Pharma Innovation Journal 2023; 12(10): 515-519

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(10): 515-519

www.thepharmajournal.com
Received: 02-07-2023
Accepted: 06-08-2023

Mohini M Dange
Assistant Professor (APE), Department of Agricultural Process Engineering, Dr. PDKV, Akola, Maharashtra, India

Pragati R Thakare
Department of Agricultural Engineering, Dr. PDKV, Akola, Maharashtra, India

Madhuri H Gajabe
Senior Research Fellow, Section of Agricultural Engineering, College of Agriculture, Dr. PDKV, Akola, Maharashtra, India

Corresponding Author:
Mohini M Dange
Assistant Professor (APE), Department of Agricultural Process Engineering, Dr. PDKV, Akola, Maharashtra, India

Drying kinetics and quality evaluation of osmo-convectively dehydrated radish cubes

Mohini M Dange, Pragati R Thakare and Madhuri H Gajabe

Abstract
The experiments were conducted to evaluate impact of convective drying behavior and quality attributes of osmotically dehydrated radish cubes. The optimized osmotically pre-treated samples in sugar solution were further dried using convective tray dryer with air temperature of 40, 45, 50 and 55 °C. The result recorded the optimum process parameters i.e., syrup temperature 52.47 °C, sugar concentration 40°B and duration or time 238.57 min for determined the various responses i.e., 53.34% water loss and 8.45% sugar gain and 80.66 colour (L). Results of validation tests were highly acceptable since the coefficient of Regression Coefficient (R greater than 0.98) and coefficient of variation (CV<5%) of the responses. The moisture content of the product was reduced with drying time in falling rate period. Drying time was observed lower in higher air temperature of 55 °C (540 min) and higher in lower temperature of 40 °C (690 min). The osmo-convective dehydrated radish cubes at 50 °C air temperature showed the best result for quality attributes i.e., colour (L* value) 80.15, water activity 0.229, rehydration ratio 2.36, hardness 1.91 kg and overall acceptability as 8.06.

Keywords: Radish, convective tray drying, drying kinetics and quality attributes

Introduction
Vegetables are an important component of daily diet and the nutritional value of vegetables as a vital source of micronutrients has been well recognized. Radish cannot be stored more than 2-3 day as it is highly perishable in nature. The shelf life of the products may be improved by using either dehydration, canning or refrigeration process thus, enhancing the storability of the product. Dehydrated vegetable products have inherent advantages, such as prolong shelf life, higher degree of resistance to bacterial attack and lower transportation, handling and storage. One effective method for reducing this huge loss would be osmo-convective dehydration.

Osmotic dehydration (OD) is an important technique of food preservation and processing in which foods especially fruits and vegetables are immersed in the osmotic solution containing concentrated salt, sugar, alcohol or starch. Osmotic dehydration is a simultaneous diffusion process which benefits the finished product by reducing the damage due to expose heat also help to maintain its flavour, colour, inhibits the browning of enzymes and decreases the energy costs when comparing to other conventional methods. Osmotic dehydration process is a simple procedure which requires decreased cost and energy consumption. It is easy to perform at room temperature, which ensures the retention of colour, texture and nutrients. Osmotic dehydration process also involves limited loss of volatile compounds and less oxidative changes.

Most researchers have studied the optimization of various techniques for radish. Use of convective tray drying is an important drying method after pre-treatment of osmotically dehydrated radish cubes over other drying method. However, there is limited research related to osmo-convective dehydrated of radish cubes. Therefore, the aim of work was to determine drying kinetics and some quality parameters of radish cubes in terms of ascorbic acid, colour, water activity, rehydration ratio and hardness.

Materials and Methods
Raw material and sample preparation
Fresh white radish was purchased from local market and then water washed, peeled and used for different experiments. Radishes were washed, cleaned from dirt, peeled using knife, sliced and cut into cubes to required 10 mm^3size. The size reduced radish is then weighed to 30 gm to standardize the amount required for various treatments of the study. Sugar was used as an 'osmotic agent'.

The syrup (40, 50, 60 °B) was prepared by dissolving required amount of sugar in distilled water. The sample to syrup ratio 1:5 was kept as constant treatment.

Drying experiments

By using RSM (response surface method) the optimum condition of osmotic dehydration of radish cubes was found. Then further convective drying at 40, 45, 50 and 55 °C air drying temperature. The optimum answers were confirmed by carrying out an osmotic dehydration experiment under ideal conditions.

Convective Drying of Osmotically dehydrated Radish cubes

Osmotically dehydrated product generally may not have moisture content low enough to be considered as shelf stable. It is therefore, needed it to be further air dried to obtain a shelf stable product i.e., stable with respect to prevention of microbial growth and enzymatic colour changes. Hence, the product obtained from the optimized levels of the osmotic dehydration was then air dried in conventional tray dryer as explained below.

Experimental Setup

A convective tray dryer was used in the dehydration experiment in this study. Tray dryer consists of drying chamber, blower, heaters and thermostat. The insulating chamber consisted of air circulating fan that moved air through heaters. The drying chamber size was 150 × 100 × 40 cm accommodating 12 aluminium trays. Trays were arranged one above the other with the clearance of 3 cm in between two successive trays to permit air circulation. The osmotically dehydrated radish cubes were loaded on the drying trays and inserted into the dryer. Drying data were recorded at 30 minutes interval until the completion of experiment.

Drying Characteristics

1. Drying rate

The moisture content data recorded during the experiments was analysed to determine the moisture lost from the samples of radish slices in particular time interval. The drying rate of sample was calculated by following formula

$$R = \frac{\text{WML}}{\text{Time interval (min)} \times \text{DM(Kg)}} \quad \ldots(1)$$

Where,

R = Drying rate at time θ, g w/g dm

WML = Initial weight of sample – Weight of sample after time θ

2. Moisture content during drying

The moisture content of radish cubes during experiment at various times was determined by oven method on the basis of dry matter of radish cubes.

Quality Evaluation

Colour, hardness, ascorbic acid, and water activity were used to assess the quality of osmo-convectively dried radish cubes. All measurements were repeated three times, with the averages published. Colour, ascorbic acid, hardness, rehydration ratio, water activity, drying duration, and general acceptability were all taken into account while determining the best temperature for convective drying.

1. Colour

Digital chromameter was used to measure the colour L value (Lightness) of osmo-convectively dried radish cubes.

2. Estimation of ascorbic acid (Vitamin C)

Ascorbic acid of processed radish cubes was determined by titration method and procedure was shown in Appendix-B.

Amount of ascorbic acid

$$\text{(mg/100 g sample)} = \frac{0.5mg}{v1ml} \times \frac{v2ml}{15ml} \times \frac{100ml}{wt\ of\ sample} \times 100 \ \ldots(2)$$

Where,

V1= working standard + oxalic acid, ml

V2= sample + oxalic acid, ml

3. Water activity (a_w)

A Hygrolab-3 water activity metre was used to detect water activity as a measure of storage stability. A 2 g sample was utilised to cover the sample cup's filling indication. Water activity values were recorded by keeping the filled sample cup in contact with the sensor probe of a water activity metre. In the image, a digital water activity analyzer is seen, which was used to measure the water activity of dehydrated radish samples.

4. Rehydration Ratio

The rehydration ratio of the radish was determined by soaking 2 g of sample in 20 ml of distilled water. The sample was left for 2 hour at room temperature. The sample was taken out and surface water was removed by blotting paper.

$$\text{Rehydration ratio} = \frac{\text{Mass of the rehydration sample,g}}{\text{Mass of dried sample}}$$

5. Texture (Hardness)

The hardness of osmo-convectively dried radish cubes was tested using a textural analyzer make the Stayble Micro System, UK; Model TA-XT2 (Texture Technologies Corp.)

Settings

Pre- Test speed: 0.5 mm/s

Test Speed: 0.5 mm/s

Post- Test speed : 10 mm/s

Distance: 0.5 mm

Trigger Type Auto: 5 g

Data Acquisition

Rate: 200 pps

Probe: 25 mm Cylinder (P/5)

Load cell: 5 kg

Result and Discussion

The optimized osmotically dehydrated radish cubes used to investigate drying characteristics.

Variation in moisture content with time

The initial moisture content of the osmotically dehydrated radish cubes was ranging 57.34 to 62.42% (wb) for all the samples investigated and after drying up to (nearly) constant weight, the moisture content was reduced in the range of 13.01 to 13.80% (wb). It can also be observed from these curves that moisture content of radish cubes decreased exponentially with drying time under all drying conditions.

Similar types of results have been reported by various researchers Jain (2007) [3], etc. for air drying of osmotically dehydrated pineapple, papaya and banana slices, respectively.
The drying data of convective drying at 30 min interval was recorded, Table 1. It can be seen that there was a wide variation in drying time required for convective drying i.e.,690, 630, 570 and 540 min at drying air temperature 40, 45, 50 and 55 °C respectively. It can also be seen that minimum time in drying was observed for higher air temperature (55 °C) and maximum time was recorded for low air temperature (40 °C).
The convective drying of osmotically dehydrated radish cubes followed a typical trend. As the drying air temperature increased, the drying curves exhibited steeper slope indicating that the drying rate increased with increase in drying air temperature. This resulted into substantial decrease in drying time at increase in temperature. This is according to kinetic theory, due to the increased energy of water molecules as temperature is increased. Hence escaping of molecules becomes easier from the medium and faster.

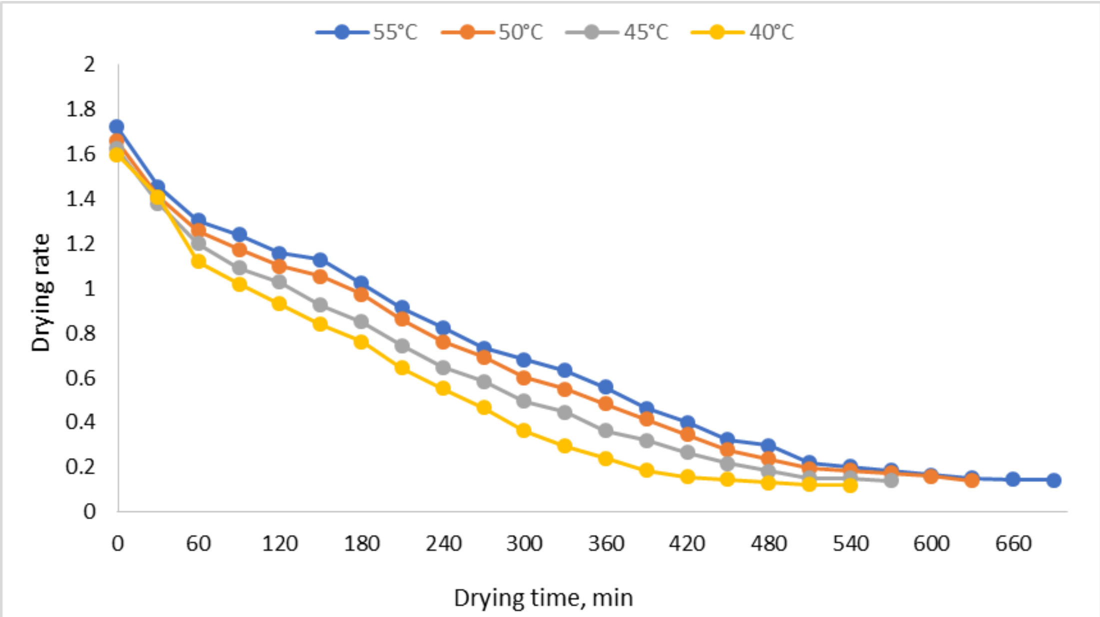

Fig 1: Variation in drying rate with drying time

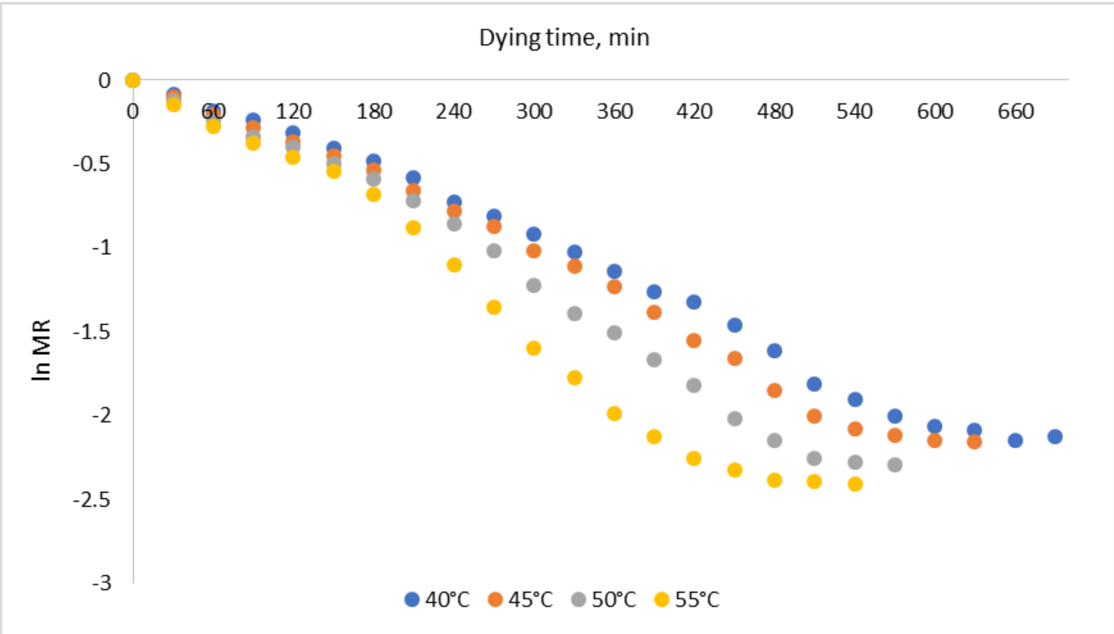

Fig 2: Variation in ln (MR) with drying time at different air-drying temperature

It can also be seen from the figure 1. that the rate of drying was higher for high temperature of drying air. This is expected also because high temperature of drying will remove moisture quickly from the sample which resulted in high drying rate. Further, it can be seen from the figures that no constant rate period was found during convective drying of osmotically dehydrated radish and entire drying has taken place in falling rate period.

Quality attributes

Optimization was carried out on various quality parameters like colour, ascorbic acid, hardness, water activity, rehydration ratio, drying time and overall acceptability. Depending upon this quality parameters the optimization for drying air temperature was carried out. The details of quality parameters given in following section.

1. Ascorbic acid

Ascorbic acid is precursor of Vitamin C and is lost during the drying process because it is heating sensible nutrient. When a food is sliced and its cells are cut, the surfaces that are exposed to air loose some vitamin C content. The retention of vitamin C depends upon the water content, sugar content, the size of the sample of food material, amount of air circulation when food is dried, the level of humidity in the air entering the dehydrator and the air temperature and time of exposure inside the dehydrator.

In the present study the ascorbic acid content of fresh radish sample was 0.16 mg/100 g dm whereas in dried sample it was observed in the range of 0.119 to 0.135 mg/100 g dm at temperature 40 to 55 °C. It revealed that the retention of ascorbic acid decreased with increase in drying temperature 55 °C. The loss of ascorbic acid at higher temperature (55 °C) is maximum because it is thermo sensitive compound (Wasu *et al*., 2006) [13]. Higher retention of ascorbic acid was observed and this might be due to long period of exposer of the product to the temperature as given in Table 1.

2. Colour value

The colour of osmo-convectively dried radish cubes was measured in terms of ΔE value (change in colour) and shown in Table 1. As the drying air temperature was increased from 40 to 50 °C. The change in colour was 80.21 at 40 °C and highest at 79.89 at 55 °C as given in Table 1.

3. Water activity

Water activities of osmo-convectively dried samples with all drying temperatures were ranging between 0.230 and 0.219 (Table 1). As regards to individual effect of temperature, it revealed that as the temperature increased water activity decreased significantly. The sample dried at 55 °C drying air temperature was having significantly lowest (0.292) water activity.

4. Rehydration ratio

The rehydration ratio of the osmotically dehydrated radish cubes at different temperatures ranges from 2.42 to 2.33. Table 1. It was observed that rehydration ratio decreased with increase in drying air temperature.

5. Hardness

Textural characteristics of osmo-convectively dried radish samples were studied in terms of hardness. Hardness of dried radish product was measured using Texture analyser. The average hardness of ten readings were taken. The average hardness values varied between 1.91 to 2.02 kg for the range of drying air temperature. It was observed that as the temperature increased, hardness increased and was highest at 55 °C temperature (2.02 kg).

Table 1: Dependant parameters for optimization of convective drying at various temperature

Drying air Temp. °C	Ascorbic acid Mg/100gdm	Colour L	Water activity	Rehydration ratio	Hardness Kg
40	0.119	80.21	0.230	2.42	1.91
45	0.125	80.17	0.230	2.36	1.93
50	0.140	80.15	0.229	2.36	1.91
55	0.135	79.89	0.219	2.33	2.02

Osmotic dehydration is an effective method combine with convective tray drying as it reduced final drying time and improved the quality of dried product. The moisture content of the product was reduced with drying time in falling rate period. Drying time was observed lower in higher air temperature and higher in lower air temperature at constant air velocity. Convective tray drying with osmotically pre-treated radish cubes exhibited better rehydration properties, lesser degradation of colour and ascorbic acid, safe water activity level at optimize conditions as compared to fresh sample of radish. Finally, it can be concluded that osmotic dehydration in combined with convective tray drying can be used for preservation of radish cubes with retention of high quality.

Conclusion

1. The optimum process parameters were 52.47 °C syrup temperature, 40°B sugar concentration and 238.57 min time for determined the various responses i.e., 53.34% water loss and 8.45% sugar gain and 80.66 colour (L).
2. The results of validation tests were highly acceptable since the coefficient of Regression Coefficient (R greater than 0.98) and coefficient of variation (CV<5%) of the responses. The moisture content of the product was reduced with drying time in falling rate period. Drying time was observed lower in higher air temperature of 55 °C (540 min) and higher in lower temperature of 40 °C (690 min).
3. The osmo-convective dehydrated radish cubes at 50 °C air temperature showed the best result for quality attributes i.e., colour (L* value) 80.15, water activity 0.229, rehydration ratio 2.36, hardness 1.91 kg and overall acceptability as 8.06.

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